

**TECHNICAL PROPOSALS FOR SOUTHEAST  
INTEGRATED ASSESSMENT**

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# TECHNICAL PROPOSAL I

## **Title: Developing Regionally Downscaled Probabilistic Climate Change Projections**

**Principal Investigator(s):** This is a collaborative project between researchers at North Carolina State University, Pennsylvania State University, and Texas Tech University. Each university, through its Cooperative Research Unit, will have a lead role for different components of the climate change analysis. The lead at each institution is as follows:

North Carolina State University: Adam Terando (PI)

Pennsylvania State University: Dr. Murali Haran (PI)

Texas Tech University: Dr. Katharine Hayhoe (PI)

### **Summary Statement:**

We propose to develop the core climatic datasets necessary to project regional ecosystem impacts resulting from 21<sup>st</sup> century climate change. We will adhere to an approach that carefully assesses and propagates model uncertainty, downscales climate projections to the scale of important ecosystem processes, and focuses on the most impact-relevant climatic variables. In doing so we will address three questions: (1) what is the magnitude and direction of climate change expected in the Southeast over the next 100 years, (2) how do the projected changes in climate relate to those parameters that most affect ecosystem processes specific to the Southeast, and (3) what is the level of uncertainty associated these projections.

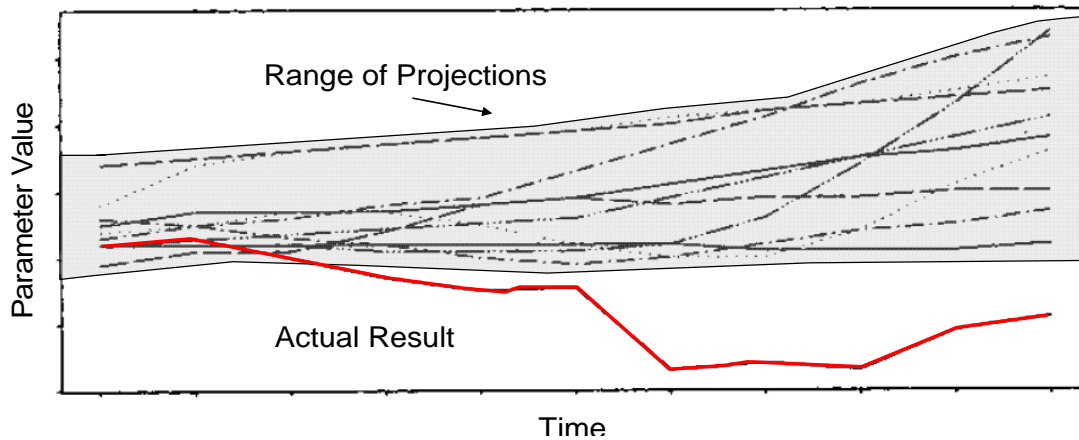
Our approach improves upon many existing impact assessments by incorporating all available Global Climate Models (GCMs) from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR4), providing new information for decision-makers through an improved quantifiable uncertainty analysis, and providing seamless downscaled ecosystem-relevant climate products for the entire Southeast. Here we describe the input datasets we will use, our methodological approach, and the product deliverables to be used by collaborators in the Southeastern Hub of the National Wildlife and Climate Change Science Center and the broader research community.

### **Problem Statement:**

The Southeast US contains the highest levels of biodiversity in North America outside of the tropics (Jose et al. 2006). This is due in no small part to the climate the region has experienced over the last few millennia, characterized by abundant precipitation, mild temperatures, and low climatic variability. Recently, the IPCC AR4 concluded that it is very likely that humans are largely responsible for increasing the global average surface temperature by 1.0 °C in the 20<sup>th</sup> century through the release of greenhouse gasses (GHG) such as CO<sub>2</sub> into the atmosphere (Bernstein et al. 2008). This warming is expected to continue well into the future and is projected to cause sizeable impacts on managed and unmanaged ecosystems (CCSP 2009). Thus, mitigation of and adaptation to the impacts of climate change on ecosystems in the Southeast will likely be the key challenge confronting natural resource managers in the coming decades.

Central to this is deciding how to best implement an adaptive management strategy given the large uncertainty associated with climate change projections. Addressing this issue requires a careful treatment of this uncertainty as well as methods to downscale the model projections to the scale of ecosystem processes because of the coarse resolution of the models. The typical approach in impact assessments is to use one or more GCMs (known as a GCM ensemble) to project future climate change based on GHG

emissions scenarios. Often the uncertainty estimate for future climate change projections is given as the range of GCM output, which may expand as more models are added to the set. However, this method can underestimate the true structural and parametric uncertainty associated with the climate change projections (Figure 1). This underestimation of uncertainty will then propagate through all levels of the regional assessment that require projections of climate change, leading to overconfident predictions. As a result, decision-makers may insufficiently hedge against the risks associated with extreme climatic events that have a low probability of occurrence, but are high impact events. Thus a severe drought or a 500 year flood event, while having a low probability of occurrence in any given year, still must be incorporated into decision-making because of its high environmental, social, and economic costs.



**Figure 1: Stylized example of underestimation of structural uncertainty leading to overconfident predictions as a result of assuming that the full range of uncertainty is equivalent to the number of models in the set (adapted from Draper 1995).**

Moreover, uncertainty also arises from the computational limits of Global Climate Models. While global-scale climate changes are reasonably depicted by GCMs, many of the unique regional signals that result from large-scale interactions with distinctive geographic characteristics cannot be resolved. In addition, these limits also often result in truncated distributions of key variables such that high-impact climate extremes are ignored. Consequently, most GCMs still have resolutions that are too coarse compared to the scale at which many ecosystem-impacts occur. Thus, high-resolution regional projections of climate change are required to accurately evaluate how climate change is likely to affect a given system. Statistical and dynamic downscaling approaches are often used to resolve these sub-grid scale processes, mitigate model biases, and correct for under sampling of the tails of distributions, thus helping to reduce this form of uncertainty (Hayhoe et al. 2008). These approaches are also subject to the same types of structural and parametric uncertainty that must be taken into account for a regional assessment in order for decision-makers to understand the full range and likelihood of possible outcomes.

## Objectives:

- Design and run an ensemble of dozens of model runs using an Earth Model of Intermediate Complexity (EMIC) to characterize the effects of parametric uncertainty on climate projections in the United States (lead PSU: Keller, Urban).
- Downscale EMIC and IPCC projections of climate variables most relevant to range and habitat dynamics (lead TTU: Hayhoe).
- Perform a Bayesian data-model fusion to weight the downscaled climate projections according to their performance and the structural uncertainty between models (lead PSU: Haran).
- Integrate climate change projections into the full Southeast regional assessment by disseminating the high resolution downscaled temperature and precipitation datasets and by developing derived climate products for the Southeast Science Hub collaborators (lead NCSU: Terando).

## Relationships to other ongoing and proposed research

The products from this research will be used by all other research teams involved in the Southeast Integrated Assessment. It is important for resource managers and decision makers to have information about those particular climate variables in a region that will have the greatest impact on the dominant processes and disturbances that drive ecosystem function. For example, insect outbreaks are a common ecosystem disturbance but the magnitude, extent, and frequency of an event is often limited by some temperature threshold related to biological activity and fitness; a threshold which may vary from species to species and from region to region. Similarly, drought is a pervasive climatic disturbance but the affect of changing drought frequency and intensity will depend on the tolerance and vulnerability of the individual species of interest within the ecosystem. Working with the core team of ecologists, biologists and hydrologists of the Southeast Integrated Assessment we have developed the following list of climate product deliverables (Table 1).

## Approach

The research methodology relies on state-of-the-art, well-documented models, data, and statistical tools. These include: (1) Coupled Atmosphere-Ocean Global Climate Model (AOGCM) simulations from the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC AR4) database archived by the Program for Climate Model Diagnosis and Intercomparison (CMIP); (2) an Earth Model of Intermediate Complexity (EMIC), the University of Victoria's Earth System Climate Model (ESCM; cf. Weaver et al. 2007, Schmittner et al. 2008); (4) statistically downscaled simulations forced by boundary conditions from 16 GCMs, the ESCM, and long-term daily weather records and reanalysis data at stations and grid-points archived by the National Climatic Data Center and the National Center for Environmental Prediction; and (5) Bayesian ensemble dressing methods developed to address structural uncertainty and the accuracy of the AOGCMs. This section describes these tools, models, and datasets, and discusses their use in this project. The entire climate change analysis is part of Phase I of the Integrated Assessment (Years 1 and 2, start date of September 1, 2009).

## GCM Dataset

***Global Climate Model (AOGCM) simulations:*** To include a representative range of forcing fields from AOGCMs, we propose to use historical and future simulations from one of each of the 16 different modeling groups that contributed to the IPCC AR4 database. Basic information about the models is

**Table 1. Direct and Derived Climate Model Products for Use in the Integrated Regional Assessment**

<b>Climate Product</b>	<b>Source</b>	<b>Spatial Resolution</b>	<b>Temporal Resolution</b>	<b>Relationship to Integrated Assessment Components</b>
Maximum Temperature	Direct Output	1/8°	Daily	Hydrologic Dynamics and Species Range Dynamics
Minimum Temperature	Direct Output	1/8°	Daily	Hydrologic Dynamics and Species Range Dynamics
Precipitation	Direct Output	1/8°	Daily	Hydrologic Dynamics and Species Range Dynamics
Evapotranspiration	Derived Product	1/8°	Daily	Hydrologic Dynamics and Species Range Dynamics
Solar Radiation	Derived Product	1/8°	Daily	Hydrologic Dynamics
Drought Index	Derived Product	1/8° - Eco-Region	Weekly	Hydrologic Dynamics, Aquatic Modeling, Species Range Dynamics, Vegetation Dynamics, Carbon Sequestration
Fire Frequency	Derived Product	Eco-Region	Monthly	Vegetation Dynamics, Carbon Sequestration
Frost Days	Derived Product	1/8°	Annual	Species Range Dynamics
Growing Season Length	Derived Product	1/8°	Annual	Species Range Dynamics
Insect Outbreak	Derived Product	Eco-Region	Annual	Species Range Dynamics, Carbon Sequestration

provided online<sup>1</sup>. Historical 20C3M simulations will be used for 1900-1999. The 20C3M simulations represent each modeling group's best efforts to reproduce observed climate over the past century. As such, they include forcing from anthropogenic emissions of greenhouse gases, aerosols, and reactive species; changes in solar output; particulate emissions from volcanic eruptions; changes in tropospheric and stratospheric ozone; and other influences required to provide a comprehensive picture of climate over the last century. Using these historical simulations, the ability of selected models to simulate regional atmospheric dynamics and surface climate patterns over North America has been previously evaluated in Hayhoe et al. (2007) and Vrac et al. (2007). Some model biases and inter-model differences emerged, particularly at higher temporal (seasonal to monthly) and spatial scales, but in general the models were able to reproduce primary seasonal patterns and climate features.

Future AOGCM simulations (2000-2099) will be based on the IPCC Special Report on Emission Scenarios (SRES, Nakićenović et al. 2000) higher (A1FI), mid-high (A2), mid (A1B), and lower (B1) emissions scenarios. These scenarios use projections of changes in population, demographics, technology, international trade, and other socio-economic factors to estimate corresponding emissions of greenhouse gases and other radiatively active atmospheric species. Although the SRES scenarios do not include any explicit policies aimed at reducing greenhouse gas emissions to mitigate climate change, the B1 scenario can be seen as proxy for stabilizing atmospheric CO<sub>2</sub> concentrations at or above 550 ppm, as levels reach this value by 2100. Atmospheric CO<sub>2</sub> concentrations for the higher A1FI scenario are 970 ppm by 2100,

<sup>1</sup> Model information available at [www-pcmdi.llnl.gov/ipcc/model\\_documentation/ipcc\\_model\\_documentation.php](http://www-pcmdi.llnl.gov/ipcc/model_documentation/ipcc_model_documentation.php)

and 830 ppm for A2. Input from these scenarios used to drive the future AOGCM simulations include regional changes in emissions of greenhouse gases, particulates, and reactive species.

***Earth Model of Intermediate Complexity (EMIC):*** In order to fully sample key climate parameters we will employ an EMIC (the ESCM) that enables production of many of climate simulations. An EMIC is not a fully coupled AOGCM, and therefore the computational costs to run the model are much less. However, it does maintain many of the dynamic features of a GCM and therefore is a useful tool to explore the full probability density function of key parameters that have a large influence on the climate system. This in turn allows for a more comprehensive treatment of parametric uncertainty that is ignored or underestimated when the IPCC GCM ensemble is used and thus provides more confidence that the uncertainty bounds around climate projections will contain the true climate change pathway.

## **Methods**

### ***Earth Model of Intermediate Complexity [lead PSU: Keller, Urban]. Total Funding Request – Year 1 \$65,000***

We will use the University of Victoria's ESCM to develop up to one hundred model runs that simulate key climate parameters that affect temperature. This method helps to compensate for the truncated probability density function represented by the IPCC AOGCM ensemble which does not sample the tails of the distribution. We will examine the impact of climate sensitivity, anthropogenic aerosol forcing, and ocean diffusivity on the climate system. These parameters have the largest overall effect on the global climate response. Climate sensitivity controls the total amount of CO<sub>2</sub> warming, aerosols are the largest and most uncertain cooling forcing which may counterbalance some of the warming, and ocean diffusivity controls the rate of warming. The global responses of these parameters will in turn affect the regional climate change experienced in the Southeast. Our approach reduces the risk of overconfident decision-making because although the probability is low that the realized future climate will track that of the less skillful EMIC runs, it is still a possibility. And this possibility must be accounted for because of the potentially significant consequences for adaptation and mitigation.

### ***Statistically downscaled simulation [lead TTU: Hayhoe]. Total Funding Request – Year 1 \$120,000, Year 2 \$90,000***

Simulations from 16 AOGCMs for the SRES A2 (mid-high) and B1 (lower) emission scenarios have been statistically downscaled to 1/8<sup>th</sup> degree resolution across the 48 contiguous states for the period 1950 to 2100 using a standard downscaling routine first described by Liang et al. (1994). This method compares favorably with dynamically downscaled projections generated using regional climate model simulations, particularly for seasonal means, as demonstrated by Wood et al. (2004) and Hayhoe et al. (2008). We will extend the downscaling approach to the ESCM runs to correct for model bias and to better approximate the full range of temperature values that are omitted due to the inability of the EMIC to resolve local scale processes. The final product will be over 100 regionally downscaled climate change projections (both EMIC and IPCC runs) of key climatic variables.

### ***Bayesian Data-Model Fusion [lead PSU: Haran]. Total Funding Request – Year 1 \$40,000, Year 2 \$35,000***

We will apply Bayesian model averaging procedure (BMA; also known as 'model dressing') (Draper, 1995; Hoeting et al., 1999) to the downscaled IPCC GCM and EMIC model ensembles to produce more accurate predictions of future climate across the Southeast while accounting for structural uncertainties across models, Bayesian prior uncertainties, and uncertainties introduced by downscaling the coarse global output to local levels. BMA calibration is a procedure for assigning probability weights to models based on how well they hindcast the observed climate. Models with better hindcast skill will receive higher weights. These weights can be used to produce a weighted average of a projected quantity in the context of a full probability density function (pdf). Historic climate data from the National Climatic Data Center and the

National Center for Environmental Prediction will be used for the Bayesian calibration and weighting procedure. We will utilize state-of-the-art techniques for reducing the heavy matrix computations (Johannesson and Cressie, 2004; Bhat et al., 2009), thereby allowing us to utilize all the data without resorting to ad-hoc aggregation approaches.

Using a Bayesian statistical approach to estimate the final climate projections is advantageous because it provides a natural framework for deriving full probability density functions that represent the degree of confidence in our predictions. This enables a more comprehensive treatment of the structural uncertainty in projections resulting from the limited sample size of the GCMs. The procedure will also reduce predictive uncertainty because the data-model fusion will properly weight the climate projections according to how well the models reproduce historic observations. These data will then be used by other Integrated Assessment researchers to produce better projections of climate-derived products such as fire frequency, insect outbreaks, and water availability, either directly through the BMA weights or through the full probability distribution of the parameters of interest given by the data-model fusion.

***Projections of impact-relevant climate indicators [lead NCSU: Terando]. Total Funding Request – Year 1 - \$82,500, \$82,500***

The statistically downscaled probabilistic projections of daily temperature and precipitation will be used to generate projections of changes in key climate indicators that have an important influence on ecosystem processes and species of interest. Impact-relevant climate indicators could consist of, for example, projected changes in consecutive days below freezing, drought intensity, and extreme heat days. The working list of variables is listed in Table 1. Climate-derived products such as fire frequency and insect outbreaks are developed through a hindcast regression method, whereby a model is developed using climate parameters as a proxy for the variable of interest that is strongly influenced by climate (e.g. fire frequency). Additional metrics to be used are determined in cooperation with the members of the Integrated Assessment (who in turn are consulting with stakeholders in the USFWS and partners in the Region 4 states). The probabilities obtained in the Bayesian data-model fusion step will be propagated to quantify climate uncertainty in the climate-derived products by more heavily weighting those impact projections driven by the more accurate climate models. NCSU will also be responsible for coordination between all lead climate change analysis partners (i.e. NCSU, PSU, Texas Tech, and USGS) and for rapid dissemination of climatic data to the aquatic and terrestrial teams.

**Timeline and Deliverables:**

Start Date: September 1, 2009

End Date: September 30, 2011

**Year 1**

- Extract IPCC GCM daily temperature and precipitation fields
- Refine protocols to use ESCM and output 100 EMIC model runs
- Downscale EMIC model runs and obtain existing statistically downscaled IPCC GCM ensembles for SE study area
- Develop protocols for Bayesian data-model fusion and extract necessary historic climate observations

**Year 2**

- Implement Bayesian model dressing methods to output probabilistic climate change projections
- Begin dissemination of climate change projections to integrated assessment team
- Implement recommendations of Integrated Assessment team to output climate-proxy models for ecosystem disturbances such as fire, insect outbreaks, and drought.
- Generate final graphics, data files, and summary report

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- Wood, A., R. Leung, V. Sridhar and D. Lettenmaier, 2004: Hydrologic Implications of Dynamical and Statistical Approaches to Downscaling Climate Model Outputs. *Climatic Change*, **62**, 189-216

## TECHNICAL PROPOSAL II

### **Title: Rapid Assessment of Regional Coastal Sea Level Rise Vulnerability and Future Sea Level Rise Inundation of the Mississippi and Alabama Coasts**

K. Van Wilson, P.E., USGS, WRD, Mississippi Water Science Center, Jackson, MS 39208, [kvwilson@usgs.gov](mailto:kvwilson@usgs.gov), 601-933-2922

Coastal inundation due to future sea level rise because of climate change will be assessed for the Mississippi and Alabama coasts. Sea level rise scenarios and its impacts on the coast will be developed with attempts to include the effects of estimates of future subsidence, accretion rates, development, and changes in tropical storm intensity. The assessment will produce maps, statistical results, and a LiDAR-based interactive map server that allows a user to select a range of sea level rise scenarios for selected areas. This study will be coordinated closely with National Oceanic and Atmospheric Administration (NOAA) and the U.S. Army Corps of Engineers (USACE).

This work is built upon the Katrina maximum storm tide work described by Turnipseed and others (2007) and on an internet map server at: [http://topotools.cr.usgs.gov/Katrina\\_viewer/](http://topotools.cr.usgs.gov/Katrina_viewer/)

Inundation areas will be determined for selected elevations above North American Vertical Datum of 1988 (NAVD88), with considerations for conversions to local tidal datums. The inundations will be determined using the selected water-surface elevation and the LiDAR-based DEM that was developed as part of the Katrina work. The NOAA tide gage records, as well as, the USACE tide gage records will be used in this study. NOAA is currently analyzing their long-term sea level records for the Mississippi and Alabama coasts. Inundation, as well as duration, of sea level rise estimates on even typical tidal conditions will be considered in these analyses. Wilson (2001) described relative rates of sea level rise for the USACE tide gages at Gulfport, Biloxi, and Pascagoula, Mississippi, and at Mobile, Alabama, and the proposed study will include analyses of the additional years of record at this gages.

#### **References**

Turnipseed, D.P., Wilson, K.V., Jr., Stoker, J., and Tyler, D., 2007, Mapping hurricane Katrina peak storm surge in Alabama, Mississippi, and Louisiana: Proceedings of the 37th Mississippi Water Resources Conference, Jackson, Mississippi, April 24-25, 2007, p. 202-207.

Wilson, K.V., Jr., 2001, Relative sea-level rise as indicated by gage data along the Mississippi and Alabama Gulf Coasts: Proceedings of the American Society of Civil Engineers World Water and Environmental Resources Congress Conference, May 20-24, 2001, Orlando, Florida, 7 p.

#### **Budget Request**

2009: \$33,000

2010: \$55,000

### **Subsidence and Accretion Rates**

NOAA Technical Report 50: Rates of Vertical Displacement at Benchmarks in the Lower Mississippi Valley and the Northern Gulf Coast will be used and is available at:

<http://www.ngs.noaa.gov/heightmod/Tech50.shtml>

Results of the Mississippi Height Modernization work will be used if it becomes available during the project to compare with rates of vertical displacement shown in the NOAA report.

Surface Elevation Tables (SETs), under the guidance and direction of Glenn Guntenspergen and his personnel, will be installed at six sites along the Mississippi and Alabama coasts. Glenn Guntenspergen's contact information is:

Glenn R. Guntenspergen, USGS, BRD, Natural Resources Research Institute, 5013 Miller Trunk Highway, Duluth, MN 55811, [glenn\\_guntenspergen@usgs.gov](mailto:glenn_guntenspergen@usgs.gov), 218-720-4307

Each site will have four SETs dispersed within the local area of the site. The installation of these SET's will help fill in a data gap that currently exists along the Mississippi and Alabama coasts (red dots in map below are current SET locations).



One year of data will at least give a comparison of the rates of subsidence or accretion in the wetlands as compared to the leveling rates of vertical displacement of the NGS benchmarks. Once these SETs are installed they can be used for data collection for future subsidence and accretion rate studies.

### **Budget Request**

2009: \$25,000

2010: \$13,000

## **A Sea Level Rise Viewer for the Mississippi and Alabama Coast**

Scott Wilson, Ph.D., Chief, Spatial Analysis Branch, USGS - National Wetlands Research Center, 700 Cajundome Blvd, Lafayette, LA 70506, [scott\\_wilson@usgs.gov](mailto:scott_wilson@usgs.gov), (337) 266-8644

### **Overview:**

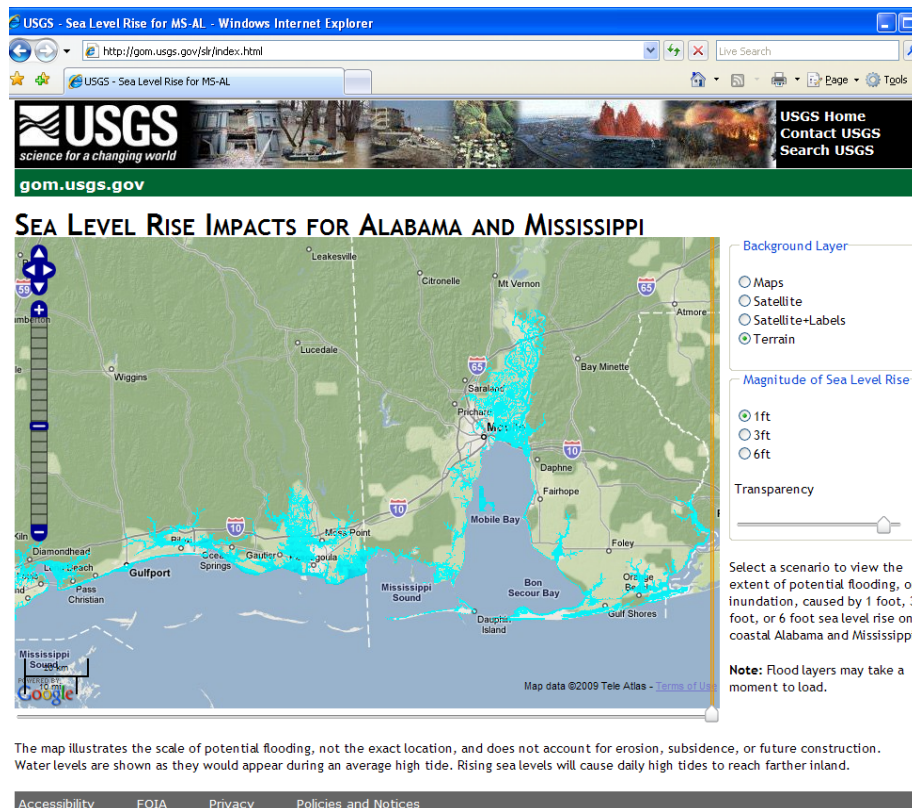
Climate change is already having substantial impacts on coastal resources and communities, and these impacts are expected to increase in scale and magnitude in the coming decades. The demand is high from many sectors for federal agencies to provide increased and improved information and services on (1) how climate change is likely to impact coastal resources and the communities that depend on them and (2) what can be done in an economical and sustainable manner to mitigate climate change and adapt to the impacts. Decision makers across the public and private sector are planning now and need tools and high quality science information to prepare, mitigate, and adapt to present and future impacts of climate change on ocean and coastal ecosystems.

### **Objective:**

The U.S. Geological Survey (USGS) will develop a Google-based map viewer that depicts inundation as sea level rises. The map viewer application provides a user-friendly and familiar environment for resource managers and the general public to visualize the potential impacts of predicted sea level rise. The interactive map viewer will allow the user to display elevations of 1 ft, 3 ft, and 6 ft above the North American Vertical Datum of 1988 (NAVD88). Additional sea level rise projections will be considered. The sea level rise inundation data developed by K. Van Wilson at the USGS Mississippi Water Science Center based on high-resolution Light Detection and Ranging (LiDAR) data.

The map viewers can display traditional maps with roads and cultural features, high resolution satellite data, or elevation data as the background layer. The sea level rise viewer will have added functionality such as the ability to change the transparency of the sea level rise data, or to control the display (on/off) through a slider tool (seen in the far eastern edge of the map in Figure 1). These tools are designed to help the user orient themselves on the map and to provide a detailed spatial context to the sea level rise data. Additional reference data (such as the U.S. Census Bureau population map) and functionality will be added. In addition, the sea level rise inundation map layers will be tiled and cached to increase page loading speeds. Because the inundation maps were developed at a very high resolution (3 meters), caching is necessary to speed the transfer of very large amounts of data.

The prototype website, shown below, will be further developed with the addition of text and graphics.



The Hurricane Katrina maximum storm tide data for Alabama and Mississippi will also be added to the map viewer application.

Links to other climate-related studies will be provided, such as the Delaware Sea Level Rise Impact effort [http://csc-s-maps-q.csc.noaa.gov/de\\_slr/](http://csc-s-maps-q.csc.noaa.gov/de_slr/). The website will provide a summary of the methods used to develop the sea level rise and storm surge data, citations, and links to reports with detailed descriptions of the data.

The web site will also build upon working for the Gulf of Mexico Governor's Alliance (GOMA). This effort will be located on the web at the following address <http://gom.usgs.gov/slr/index.html>

### Technical Objectives:

- 1) Develop a front end interface. The front end interface will be made using the javascript language and the open layers library. Code must be written to layout the open layers map and map controls, enable special functionality such as the swipe tool, and access the map server.

- 2) Develop back end map server. The back end is a map server which serves the actual overlaid sea level rise data. This server must be configured to serve the sea level rise data layers, which will be linked to open layers controls in the front end interface.
- 3) Optimization caching and layers for enhanced user performance.
- 4) Development of HTML web site and add additional SLR-related content.
- 5) Migrated to public servers

### **Budget Request**

2009 \$40,000  
2010 \$20,000

### **Geologic Assessment of Open-Coast Sea-Level Rise Vulnerability for Mississippi/Alabama Using a Bayesian Network Approach**

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#### **Description:**

Improving the ability to predict future sea-level rise effects on coasts is a major challenge. For example, predicting changes in shoreline position and land loss resulting from erosion is difficult due to the complexity of coastal systems. This complexity arises from the wide range of variables and related feedbacks that influence responses to rising sea level. In addition to uncertainties in future sea-level rise, there are large uncertainties in predictions of future climate conditions (e.g., storms) that drive the relevant physical and biological processes. We will employ a Bayesian statistical framework that incorporates a wide range of geologic and oceanographic information about coastal systems, including uncertainties in physical properties and process characterizations, to make probabilistic predictions of the future state of coastal environments. Inputs to the prediction include datasets that provide information regarding the initial states of coastal systems, relevant forcing factors, historical observations, and model projections. Competing hypotheses for the forcing are used to drive the model and resulting response scenarios and their uncertainties are compared. Initial results from the U.S. mid-Atlantic coastal region demonstrated this approach. These capabilities include risk analysis for decision support, providing a framework to engage decision makers and to help to define and address specific management questions related to sea level rise. In addition, Bayesian analysis can also be used to prioritize research needed to reduce uncertainty in predictions.

#### **Statement of Work:**

In year 1, we will develop a Bayesian network for open ocean coastal response to sea-level rise using methods described above, which are similar to that used for the U.S. Atlantic (project

funded by USGS Global Change Program). Compare and contrast two available datasets for the Gulf of Mexico coast: a) Thieler and Hammar-Klose (2000) 8 km resolution for FL to LA, and b) Pendleton et al. (2003) 1 km resolution and new data from USGS National Assessment of Coastal Change Hazards project for Gulf Islands National Seashore (and potentially Dauphin Island as well). In year 2, we will integrate results of the open ocean coastal effort with existing project work in adjacent wetland environments.

**Linkages to USGS Science Strategy:**

We provide linkage to several goals: 1) Understanding and predicting ecosystem change. We are examining components of coastal ecosystems (e.g., barrier islands and associated environments) and the factors that contribute to changes in these systems (e.g., sedimentation). Our approach will enable forecasts of coastal response to SLR. 2) Climate variability and change. We are integrating multidisciplinary scientific knowledge, identifying areas for new inquiry to understand past changes, and assessing consequences of future changes. 3) National hazards, risk, and resilience assessments. We are building on previous and ongoing work to develop quantitative, probabilistic assessments of coastal vulnerability that inform decision support systems for coastal managers.

**Budget Request**

2009	\$27,000
2010	\$32,000

## **Rapid Assessment of Regional Sea-Level Rise Vulnerability in the Southeast using the SLAMM Coastal Change Model**

Alexa McKerrow, USGS, BRD, North Carolina State University – Raleigh, NC, 27695-7617 [amckerrow@usgs.gov](mailto:amckerrow@usgs.gov), ofc 919-513-2853; Adam Terando, NCSU, North Carolina State University – Raleigh, NC, 27695-7617 [ajterand@ncsu.edu](mailto:ajterand@ncsu.edu), ofc 919-513-7292.

### **Description:**

Sea level rise is an important regional climate change impact to consider because of its possible effects on built, managed, and natural environments. We will use the Sea Level Rise Affecting Marshes Model (SLAMM; Clough and Park 2008; Park et al. 1986) to identify coastal habitat change and land surface loss through wetland conversion and shoreline modification. The physical and biological interactions spurred by sea-level rise are complex, with local processes being dictated not by a simple change in shoreline location (i.e. “a filling bathtub”), but include processes such as salt water intrusion and alterations to ground water, increased rates of erosion, and changes in deposition rates. The SLAMM model accounts for inundation, erosion, over wash and saturation and was intended to provide a regional perspective on vulnerability to sea-level rise. We will implement the SLAMM model using USGS's 8 digit hydrologic units (HUCs). Model development by HUC allows for localization of important inputs such as tidal vertical datum and range, offshore direction, mean spring high water level, and historic sea level rise trend. This data is available through NOAA National Ocean Service stations located along the coastal United States and Great Lakes region. We have already developed a cross-walk from the U.S. Fish and Wildlife Service’s National Wetlands Inventory (NWI) attribute codes for the Southeast to the 23 general classes used in the model, including conflation with Southeast GAP land cover developed classes. We have also modified the National Elevation Dataset (NED) data to partially eliminate inconsistencies and artifacts. Impervious surface from the National Land Cover Dataset is incorporated as well. Finally four IPCC climate change scenarios will be used to drive the region-wide sea-level rise projections (A1B, A2, B1, and A1FI).

### **Statement of Work:**

We will complete the regional sea level rise projections for the entire Gulf and southeastern Atlantic coasts in year 1 of the Southeast Integrated Assessment. The projections will be used for a rapid assessment of relative vulnerability to sea level rise between coastal areas and will be integrated into the vegetation dynamics modeling being completed by the NCSU coop unit.

### **Management Relevant Outcomes:**

The sea-level rise projections produced here will provide two tiers of management related information. At a sub-regional level SLAMM model outputs inform vegetation dynamics modeling along coastal ecosystems and ultimately species distribution models. At the regional extent, areas vulnerable to sea-level rise will be identified and can be prioritized for monitoring.

### **Budget Request**

2009 \$32,000

## TECHNICAL PROPOSAL III

### **Title: Climate Change in the Southeastern U.S. and its Impacts on Bird Habitats**

**Principal Investigator:** James (Barry) Grand, Leader, USGS, Alabama Cooperative Fisheries and Wildlife Research Unit, 3301 Forestry and Wildlife Sciences Building  
Auburn University, Auburn, AL 36849-5418

**Summary Statement:** This proposal will provide additional funding necessary to develop critical information for linking projections of climate change in the southeastern U.S. to wildlife habitats and populations. The goals of this project are to provide data on historic landscape conditions and estimate the recent (since 1970) rates of landscape change in the Southeast. These data will be useful for examining changes in the range dynamics of birds and other wildlife as they adapt to projected climate and habitat changes.

**Problem Statement:** Fish and wildlife agencies are challenged to plan and respond to potential changes in climate. Global Climate Models (GCMs) developed under the Intergovernmental Panel on Climate Change (IPCC) predict changes in temperature and rainfall patterns throughout much of North America. These changes are expected to cause substantial changes in habitat conditions and thus species distributions. Current models have generally predicted increased temperatures and shifts in storm duration and intensity over much of the Southeastern region when run at a continental scale. Such climatic shifts add yet another dimension of uncertainty when Fish and Wildlife Agencies formulate management plans that are based on historical trends of population abundance. Terrestrial landscapes can be expected to change yielding altered forest and terrestrial ecotypes, to the extent that species distributions and migratory patterns for birds and other species may dramatically change. State fish and wildlife agencies will need to respond to a changing climate and incorporate it into their planning efforts. Only recently have models been tested that provide any degree of certainty for sub-regions of the United States. A more fine-scaled approach to predict climate changes related must be established before effects on animal habitats and populations can be predicted. Such an approach will enable states to make informed, adaptive decisions in their planning for their fishery and wildlife resources. The research proposed here seeks to estimate the rates of historic change in land use-land cover (LULC) in response to changes in key climate parameters.

#### **Objectives:**

1. Determine the spatial and thematic resolution necessary to estimate the relationships between recent changes in land use and land cover (LULC) and the distribution of bird populations.
2. Estimate historic LULC at decadal intervals between 1970 and 2006 using available Multi-spectral scanner (MSS) and LandSat Thematic Mapper (TM) data at spatial and thematic resolutions that will be useful for conservation of fish and wildlife populations.
3. Estimate rates and uncertainty in historic LULC change at decadal intervals between 1970 and 2006 and their relationship to important climatic and abiotic factors that govern LULC.

#### **Relationships to other ongoing and proposed research**

Estimating historic effects of potential climate change on habitats.—The habitat requirements of birds are a complex interplay of land cover, vegetative structure, and landscape characteristics. Projecting future bird habitat conditions in particular requires predicting not only changes in LULC, but also changes in the

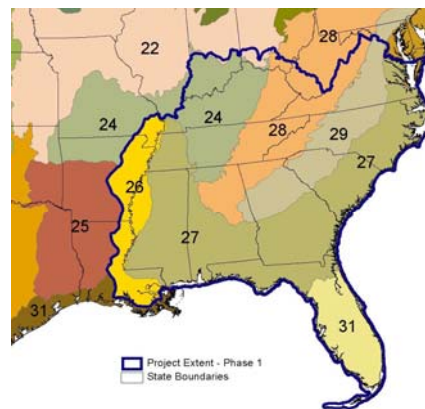
structure and arrangement of land cover types and the disturbance regimes, natural and anthropogenic, that affect them. Useful, comprehensive, predictive models must employ the expected changes in precipitation and temperature as well as the complex interplay of abiotic components such as soil types, elevation, and slope to project the likely changes in land cover and ensuing landscape dynamics. These relationships can be captured in state-based transition models that incorporate uncertainty in the effects of climate on vegetation and the limitations imposed by the abiotic environment. ALCFWRU staff and students will map LULC and changes in LULC, and then use these data to estimate the rates of change in bird habitats based on historical climate data. These land cover data will be useful for estimating habitat-related changes in bird distribution and vital rates (see below). The transition rates among habitats related to climatic parameters will be useful for projecting the change in bird habitats and distributions based on output from the probabilistic climate change projections developed as part of this integrated assessment.

Estimating the effect of climate and landscape change on range dynamics of birds.—Staff and Students from North Carolina Cooperative Fish and Wildlife Research Unit (NCCFWRU) will use models of occupancy dynamics that incorporate temperature changes as well as observed changes in habitat to assess the extent of the potential change in avifauna patterns in the southeastern U.S. Coupling climate change data over the past 3 decades with large scale bird surveys (e.g., the North American Breeding Bird Survey - BBS) will permit inference about avian responses to past change that can be used to develop models for projecting future avian responses. For example, range expansion is expected near northern boundaries of species ranges and range contraction near southern boundaries. We expect that the approach developed here for avifauna can serve as a framework for other species and taxonomic groups as the necessary data are collected and organized.

**Project Scope:** See Figure 1. – Bird Conservation Regions 24 (part) 26, 27, 28 (part), 29 (part), and 31.

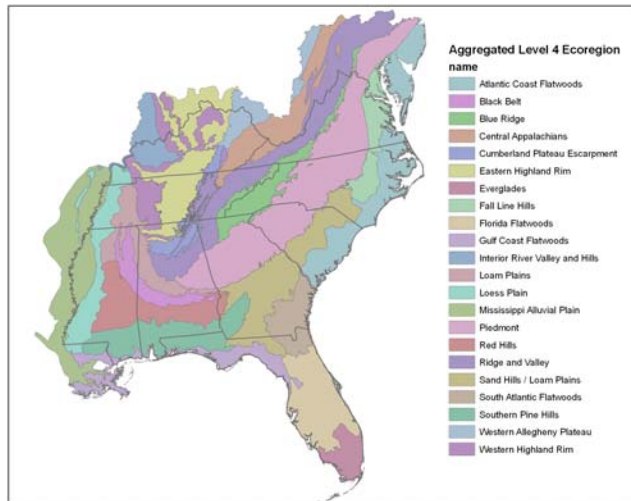
## Approach

We will largely follow the approach developed by the Land Cover Trends Project (Loveland et al. 2002). Source imagery will be the North American Landscape Characterization (NALC) Triplicates which contain Landsat Multi-spectral Scanner (MSS) images from 1973, 1986, and 1991. Although many automated techniques for detecting land cover change exist (Yuan and Elvidge 1998), consistently accurate measurements of land cover change can best be ensured using manual image interpretation (Sohl et al. 2004). However, manual interpretation of LULC change at the full spatial resolution of the data is not feasible for the entire spatial scope of this project. Therefore, we will determine change on a stratified random sample of BBS routes that were consistently monitored between 1974 and 2006. The stratification will be based on an aggregation of Level 4 Ecoregions (see Figure 2) (Omernik 1987, 1995) and the land cover classification will be based on modified Anderson Level 2 legend. The finer stratification and greater thematic resolution more accurately represents avian (wildlife) distributions.



**Figure 1.** The blue line indicates the extent of the proposed project.

Additionally, we will develop estimators for each transition probability based on a priori hypotheses regarding the factors that influence change from one class to another. For example, the probability change from mixed forest to other classes (e.g., pine forest) within the eastern portions of the Southeast Coastal Plain ecoregion may be influenced by anthropogenic factors related to regional land use practices or changes in temperature and precipitation. Competing models will be evaluated based on multinomial maximum likelihood estimators employing link functions to estimate the odds of change based on ancillary datasets (e.g., proximity to population centers and transportation corridors (anthropogenic) or frequency and severity of drought (climatologic)). The corresponding models will be compared using information theoretic methods (Burnham and Anderson 2002). The final result will be estimates of the rates of change among LULC classes; as well as, the best approximating models relating climatic and anthropogenic factors to observed change.



**Figure 2.** Proposed strata for sampling BBS routes.

**Project Status:** Initial funding for this project was received in September of 2008. Some of the NALC triplicates of remotely-sensed data have been acquired and integrated into GIS including SEGAP LULC data LULC and ancillary data sets. Several existing data sets and approaches to estimating and interpreting LULC change using automated and manual techniques were tested before a protocol for manual interpretation was adopted because it allowed for greater thematic resolution and sampling at a wide variety of spatial scales. We have acquired some of the spatially explicit climatic data from NCDC. Additional data will be acquired as a priori change hypotheses are developed. The search for additional staff to assist with image interpretation is underway. Discussions are ongoing with NCCFWRU and Patuxent Wildlife Research Center staff to determine a stratification scheme that will allow for the desired analysis of avian range dynamics.

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**Budget:**

<b>Item</b>	<b>FY2009</b>	<b>FY2010</b>	<b>Total</b>
<b>Salaries</b>			
Research associate IV	\$8,742	\$46,072	\$54,814
Research Assistant I	\$22,258	\$31,928	\$54,186
Graduate Res Asst (MS-6 mos)	\$7,770	\$7,770	\$15,540
Benefits for full-time staff (28.5%)	\$8,835	\$22,230	\$31,065
<b>Total Salaries &amp; Benefits</b>	<b>\$47,605</b>	<b>\$108,000</b>	<b>\$155,605</b>
<b>Travel for project coordination</b>			
Air fares (4 @ \$150)	\$600	\$600	\$1,200
M&IE (@ \$110/day)	\$1,760	\$1,760	\$3,520
<b>Subtotal</b>	<b>\$2,360</b>	<b>\$2,360</b>	<b>\$4,720</b>
<b>Total for Indirects</b>	<b>\$49,965</b>	<b>\$110,360</b>	<b>\$160,325</b>
<b>AU Overhead (12%)</b>	<b>\$5,996</b>	<b>\$13,243</b>	<b>\$19,239</b>
<b>Total Funding to AU</b>	<b>\$55,961</b>	<b>\$123,603</b>	<b>\$179,564</b>
<b>USGS Overhead (6%)</b>	<b>\$3,358</b>	<b>\$7,416</b>	<b>\$10,773</b>
<b>Total Funds Required</b>	<b>\$59,318</b>	<b>\$131,019</b>	<b>\$190,337</b>

**Timeline:**

Start Date: September 1, 2009

End Date: September 30, 2011

Year 1

- Obtain appropriate remotely-sensed data
- Obtain existing LULC data, DEM derivatives, and soils data
- Begin interpretation of remotely-sensed data

Year 2

- Continue interpretation of remotely-sensed data
- Development/attainment of historical climatologic data

Year 3

- Complete interpretation of remotely-sensed data

- Analysis of LULC change within sampling strata
- Reporting

**Products:**

- Reports and publications describing the results of the change detection analysis and the rates of change in relation to climatologic change including:
  - Estimates of LULC and rates of change within strata for each decade.
  - Estimates of relationships between rates of change, climate, and
  - LULC change data comparing each regional coverage
- **Educational Component:**
- This project will be used to support one M.Sc. student for one year to gain experience with LULC change detection and estimation of rates. If additional funding can be secured, that student will also work on the projection of future conditions.

## TECHNICAL PROPOSAL IV

**Title: Designing Sustainable Landscapes: Climate and Land Use Change Projected Impacts on Priority Species Habitats in the Southeastern U.S.**

**Principal Investigator:** Jaime A. Collazo, USGS, North Carolina Cooperative Fish and Wildlife Research Unit, 226 David Clark Labs, North Carolina State University, Raleigh, NC 27695-7617

**Summary Statement:** The research proposed here will provide the habitat dynamics models that will serve as the basis for a detailed regional assessment of priority species habitats. This work builds on the modeling protocols that have been developed as a part of the ongoing “Designing Sustainable Landscapes” Project. The goals of the work include developing region-wide projections of urban growth, sea-level rise (previously mentioned in the coastal dynamics section), and habitat dynamics models for priority species from 2001 to 2100. The work will be staged to provide urban growth and sea-level rise models in year 1 and the detailed habitat models in year 2.

**Problem Statement:** In the Southeast U.S., fish and wildlife agencies are increasingly challenged to predict and respond to the potential effects of a changing climate and land use change. Of primary concern to agencies seeking to implement long-term conservation strategies is the rapid urbanization, threat of sea-level rise, and potential shifts in climate that will directly and indirectly impact habitat availability and quality for priority species. The increased stress on ecosystems brought on by urbanization and changes in land use is exacerbated by climate change. Specifically, primary disturbance agents in the Southeast such as insects, fire and drought will be impacted by changes in climate. Urbanization will in turn have an effect on these processes through human actions such as fire suppression and increased water demand. Thus, the effective conservation of fish, wildlife, plants, and their habitats will require the development of a conservation system with the ability to evolve and adapt to these changing conditions. Modeling the future range of landscape conditions under a variety of policy and land use scenarios is an effective way in which to provide managers the information they will need to adaptively manage for species.

### **Objectives:**

1. Region-wide urban growth projections through 2100 (Year 1)
2. Sea-level rise projections through 2100 (Year 1)
3. Vegetation and Species Habitat Dynamics
  - a. Mississippi/ Alabama Coastal Counties (Year 1)
  - b. Priority terrestrial species in the Apalachicola-Chattahoochee-Flint Basin (Year 2)
  - c. Region-wide species habitat dynamics modeling (Year 2)
4. Habitat models for Priority Species through 2100.
  - a. Mississippi/ Alabama Coastal Counties (Year 2)
  - b. Priority terrestrial species in the Apalachicola-Chattahoochee-Flint Basin (Year 2)
  - c. Region-wide Priority Species Models (Year 2)

### **Relationship to other ongoing and proposed research:**

Regional Climate Change and Uncertainty Projections: The down-scaled regional climate data will be used to refine the projections of ecological processes, specifically the relationships between climate data and fire probability have been hind cast to develop relationships between the acres burned and climate variables has been used to inform the vegetation dynamics model through a fire probability multiplier. In the future the uncertainly projections will be used to provide a more throughout understanding of the probable range of those projections based on the 4 climate scenarios (A2, A1B, B1 and A1FI).

Designing Sustainable Landscapes: The approach for prioritizing species and habitats through structured decision making, modeling the range of future conditions, and creating priority surface maps being proposed in this integrated proposal are based on ongoing work funded by the Association of Fish and Wildlife Agencies in collaboration with the Atlantic Coast Joint Venture Program. That effort is focused on the Southern Atlantic Migratory Bird Initiative Area (SAMBI) in this effort we will be expanding that work to the entire Southeast Region in conjunction with Alabama Cooperative Research Unit staff and students and the work proposed in the Optimal Conservation Strategies to Cope with Climate Change proposal.

Coastal Dynamics – Mississippi/Alabama Coastal Counties. The urbanization and vegetation dynamics work will be prioritized for the Mississippi and Alabama coastal counties in order to integrate the potential impacts of those land use changes with the refined modeling of the impacts of climate change on coastal processes. Both the urban model, SLEUTH, and the vegetation dynamics model (VDDT, TELSA) will be calibrated to the local conditions for the ecological processes most relevant to the ecological systems (e.g. East Gulf Coast Maritime Forest, Mississippi Sound Salt and Brackish Tidal Marsh) and species (e.g. *Bufo valliceps* (Gulf Coast Toad), *Heterodon simus* (Southern Hognose Snake), *Mustela frenata* (Long-tailed Weasel), *Elanoides forficatus* (Swallow-tailed Kite)) that occur there.

Optimal Conservation Strategies to Cope with Climate Change: The species and their habitats in the work proposed here are guided directly by the priorities set in the workshops and structured decision making process of the Optimal Conservation Strategies work being conducted at the Alabama Cooperative Fish and Wildlife Research Unit. The outputs from this work are required inputs for developing the final priority surfaces for the regional assessment.

Southeastern Gap Analysis Project: The species habitat models, land cover and land stewardship data from the Southeastern Gap Analysis Project are the baseline datasets for much of the proposed and ongoing work. Stewardship data are used to set exclusion layers for the urbanization modeling, the detailed land cover is used in the habitat affinity models that are the starting point for the Habitat Suitability Models being used as input into the landscape conservation priority surfaces.

**Project Scope:** Our project extent covers the Region 4 of the U.S. Fish and Wildlife Service and extends north to include Virginia and parts of WV, IN, and OH. In Phase 1 we will create habitat dynamics, urban growth, and sea level rise models for a variety of land use and conservation strategies. Those strategies will be modeled relative to projections of future conditions based on management actions as well as four carbon emission scenarios (A1, B2, A1B, and A1FI). Regional policy related scenarios (e.g. increased biofuel production, changes in the enrollment in

the conservation reserve program will be run for the entire region. In addition to the management scenarios for the full extent, an early emphasis on sub-regional management actions within the Mississippi/Alabama focal area as well as the in the Apalachicola-Chattahoochee-Flint Basin will be modeled. Phase 2 may include geographic expansion of the modeling, as well as concentrated efforts on additional focal areas based on partner and agency interest.

**Approach:** The approach is similar to that applied in the Designing Sustainable Landscapes project. We will work with the personnel from the Alabama Cooperative Fish and Wildlife Research Unit (ACFWRU), Fish and Wildlife Joint Ventures Program, and the regional Fish and Wildlife Biologist throughout the project. The ACFWRU personnel will lead workshops throughout the region to identify priority species and the limiting and compensatory factors that determine sustainability for each. Our team is then charged with developing the landscape dynamics models (urban growth, sea-level rise and vegetation dynamics) through 2100. Details for each of the modeling components follow.

*Urban Growth Modeling:* We will use the SLEUTH model within the USGS's Gigalopolis framework (<http://www.ncgia.ucsb.edu/projects/gig/>) to model spatially explicit urban growth throughout the study area. SLEUTH (Slope, Land use, Exclusion, Transportation, and Hillshade) uses cellular automaton modeling to predict the probability of each "cell" being developed through time (Clarke 2008, Clarke and Gaydos 1998). Five of the six input datasets needed are currently available through USGS Programs, specifically the National Elevation Dataset (slope and hillshade), the National Land Cover Dataset (general land cover and urban land use) and the National Gap Analysis Program (detailed land cover and land management and ownership). Finally, the sixth input dataset, the transportation corridors are provided through the U.S. Census Bureau in the Topographically Integrated Geographic Encoding and Referencing (TIGER) system.

In order to calibrate the SLEUTH model, we will develop four dates of urban land use maps (centered around 1992, 1996, 2001, and 2006). Candau (2002) found that calibrating with recent data (1963 – 1997) resulted in better performance than did models based on a long history (1929 – 1998) of training data. We will use the 2001 NLCD impervious surface dataset to train and estimate impervious surface from LANDSAT TM imagery for the remaining three dates. A threshold is then applied to the impervious surface estimates to classify urban categories consistent with the 2001 NLCD land cover classification (open space developed, low, medium, high density urban). Four dates of roads coverage are created based on the TIGER road files for use in the calibration phase. We have found based on our previous work in the SAMBI, filtering the urban data based on road density helps remove noise (scattered isolated urban pixels) and identifies areas where urban areas had been mis-classified as non-urban due to high canopy closure in older more established neighborhoods. The exclusion layer will be developed using the GAP Stewardship and land cover datasets. Public lands, private conservation lands, and open water are excluded from development, while certain land cover types (e.g. wetlands) are assigned a lower probability of development.

Once the input datasets are finalized, monte-carlo simulations are used in the calibration phase and one of the fit statistics (Lee and Sallee or Compare) will be used to set the parameter (dispersion, breed, spread, and road growth) values. There is no general consensus on the best fit

statistic, however Lee Sallee (ratio of the intersection to the union of observed vs. predicted urban for each calibration year) and Compare (ratio of the modeled population to the observed for the final calibration year) optimize for the characteristics we are most interested in for this research. In addition, we will test sensitivity to the output using the combined fit statistic (Lee Sallee \* Compare) to determine how that choice impacts the pattern and extent of the projected growth (Jantz and Goetz 2005).

#### Management Relevant Outcomes

The resulting dataset, probability of urbanization in yearly increments will be used in conjunction with the sea-level and vegetation dynamics models to produce land use and habitat maps for priority species from 2001 - 2100. As mentioned previously those maps will then be provided to the ACFWRU for use in generating the regional conservation priority surfaces.

Sea-Level Rise Model See Technical Proposal II.

Vegetation and Species Habitat Dynamics We will use ESSA Technologies' vegetation dynamics modeling framework (TELSA in combination with VDDT) to derive spatially-explicit probabilistic predictions of land cover change through time. That framework relies on state transitions models to project the future condition of individual patches on the landscape. The transitions are Ecological System or land cover type (i.e. plantation pine) specific. The Nature Conservancy in collaboration with the LANDFIRE Interagency Project held a series of workshops for vegetation ecologists to populate those models. Experts were asked to identify the successional states for each vegetation type and then to describe the probabilities and responses to a series of ecological processes (e.g. succession, fire, insect outbreak). Those models in combination with the 2001 Southeast Gap Land Cover map provide the basis for the vegetation dynamics modeling. For each patch in the landscape the map is attributed with the initial condition (cover type, stage and state). For this effort we will use the Forest Inventory and Analysis (FIA) data to obtain the initial stand structure characteristics for each of the forest types. For each time step (one year) transitions are applied to each patch. A patch either succeeds to be a year older or a disturbance occurs and the state for that patch is changed. For example, if a patch of longleaf pine woodland has a surface fire, the understory would become "open".

The impact of climate change is currently incorporated in the vegetation dynamics model through a fire probability multiplier. The trend for the multiplier was determined by relating historic climate observation data with the area burned in each year in the SAMBI study area. That relationship is then applied to the projected climate in 4 IPCC scenarios (A1B, A2, B1, and A1FI) to develop the trend line for fire probability for each one. Probability of a fire in each patch on the landscape is then determined by the current state of the patch, the original probability of a fire for that system in any one year, and the fire multiplier value for the time step being modeled.

In this project the regionally down-scaled climate variables, as well as the uncertainly projections being developed at Pennsylvania State University will be incorporated to determine fire probabilities at a finer spatial resolution and to provide measures of the variability around those probabilities. Finally, climate projections will be used to model the potential impact of insect

outbreak on vegetation dynamics. Currently the VDDT models include disturbances due to insects, but the potential for a change in the severity or extent due to insect population responses to changes in climate have not been modeled.

The resulting vegetation dynamics models provide yearly snapshots of the landscape condition which can be used to model habitat availability using the habitat affinity models described below. These same landscape snapshots will be also be used as inputs into occupancy models for species in which sufficient observation data exists to develop estimates of species occupancy relative to landscape condition.

#### Management Relevant Outcomes

These landscape models will provide information for assessing the potential impact of climate change on the Ecological Systems of the Southeast region. For example, if there are areas where fire frequency is projected to increase dramatically that will have important implications for fire dependent systems, as well as for the human population that co-exist. Indirectly these landscape models provide the basis for the habitat models for the priority species throughout the region.

Habitat models for Priority Species through 2100 In assessing the impacts of landscape change on priority species throughout the Southeast; we will employ a knowledge-based model approach utilizing habitat suitability indices (HSI; Schamberger et al. 1982). This approach allows us to incorporate species that do not have adequate sampling throughout the range of environmental conditions it experiences across the region. Relatively few species are well represented throughout their range with observation data; therefore we limit the modeling for many species to habitat affinity modeling so that they may be addressed in the context of conservation planning. The basis of the species habitat models will be taken from the recent Southeast GAP Analysis Project dataset. In that effort, species habitats were modeled based on habitat preferences derived from literature and expert opinion compiled in a wildlife habitat relationship database. Models were then created in a Geographic Information System environment to produce a spatial representation of predicted habitat (Scott et al. 1993). In addition to species' use of land cover map units, further restrictions were applied in the form of known range and other environmental factors that could be represented with remotely sensed data (e.g. elevation, water affinity, anthropogenic disturbance) (<http://www.basic.ncsu.edu/segap/downloads/SE-GAP%20Ancillary%20Data%20Metadata.pdf>). This effort will expand on the presence/absence representation of GAP models by incorporating suitability rankings of habitat parameters through a series of workshops with biologists throughout the region. Each parameter will be identified as compensatory or limiting in nature and the resulting spatial models will be depicted as a continuous surface.

The results of the first three objectives (urbanization, sea-level rise, and vegetation dynamics models) are compiled to create a series of maps represented the projected landscape condition. At each time step the landscape maps are then translated into a habitat for each of the priority species. Species maps can then be combined to create the priority conservation surface through time.

#### Management Relevant Outcomes

These species models will directly inform the conservation planning efforts at the ACFWRU. Projections based on a range of management and policy scenarios will provide managers the ability to consider spatially explicit "what if scenarios". The changes in habitat availability and pattern projections can then be used to assess actions (e.g. restoration planting, land conservation).

**Project Status:** Many of the approaches described here are being applied throughout the Southern Atlantic Migratory Bird Initiative Area through the Designing Sustainable Landscapes Project. The work proposed here is an expansion of that work from a single Bird Conservation Region to the entire Southeast Region. While the methods have generally been developed, research specific to processes that vary in their importance as drivers of landscape change will be required throughout the effort. For example, insect outbreaks are expected to be a more important driver in the piedmont than in the coastal plain, while, fire is central to determining habitat dynamics throughout much of the coastal plain. Throughout the region urban growth has tremendous potential to determine future condition, but interactions are likely to change (e.g. fire suppression, blocking migration corridors).

**Timeline:**

**Year 1**

- Ecological Systems Map for 1992 and 2006 to support occupancy modeling.
- Urban growth modeling throughout the Southeast Region.
- Sea-level rise modeling throughout the Southeast Region under 4 emission scenarios (A2, B1, A1B, and A1FI).

**Year 2**

- Vegetation Dynamics in the Mississippi/ Alabama Coastal Counties
- Species suitability models for the Mississippi/Alabama Coastal Counties
- Vegetation Dynamics in the Apalachicola-Chattahoochee-Flint Basin
- Species suitability Models for ACF Basin
- Vegetation Dynamics Modeling Region-wide
- Species Suitability Models Region-wide

**Future Efforts Planned for Phase 2.**

- Continued Modeling Support for the Optimal Conservation Strategies: Vegetation and habitat dynamics modeling under a variety of management and conservation scenarios.
- Change detection to update vegetation and land cover maps to reflect current conditions (2006, 2011 region-wide).

## Budget

Objective	Task	Lead	TOTAL	FY 2009	FY 2010
<b><i>Climate Change in the Southeastern U.S. and its Impacts on Bird Distributions and Habitats</i></b>					
	<i>Complete modeling of avian species range dynamics</i>	Collazo	80,000		80,000
<b><i>Designing Sustainable Landscapes: Climate and Land Use Change Projected Impacts on Priorities Species Habitats in the Southeastern U.S.</i></b>					
	<i>Ecological Systems Map 1992 &amp; 2006 to Support Occupancy Modeling</i>	McKerrow	32,000	32,000	
	<i>Complete Urban growth Modeling Regionwide</i>	Terando	88,000	44,000	44,000
	<i>Vegetation Dynamics Regionwide</i>	McKerrow	64,000		64,000
	<i>Priority Species Habitat Suitability Models Regionwide</i>	Williams	32,000		32,000
	<i>Vegetation Dynamics for MS/AL Coastal Counties</i>	McKerrow	12,000		12,000
<b><i>TOTAL COST</i></b>			308,000	76,000	232,000

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## TECHNICAL PROPOSAL V

**Title: Patch and range dynamics of North American avian species in response to land use patterns and climatic change in Southeastern United States.**

**Principal Investigators:** Jaime A. Collazo, USGS, North Carolina Cooperative Fisheries and Wildlife Research Unit, 225 David Clark Labs, Dept. of Zoology, North Carolina State University, Raleigh, NC 27695; James D. Nichols, J. Andrew Royle, and John R. Sauer, Patuxent Wildlife Research Center, 12100 Beech Forest Rd., Laurel, MD 20708

**Summary Statement:** This project will predict the effects of land use changes and climate change on selected bird populations at the level of Bird Conservation Regions (BCR) and states based on Regional Circulation Models (RCM) for the SEAFWA region. Coupling climate change data over the past 3 decades with large scale bird surveys (North American Breeding Bird Survey - BBS) will permit inference about avian responses to past change that can be used to develop models for projecting future avian responses. This effort will begin by specifying *a priori* hypotheses about avian change in response to changes in landscape and climatic changes. We will use recently developed occupancy models to estimate parameters associated with avian dynamics, while accounting for imperfect detection. As models are simultaneously developed for habitat responses to climate change, we will also describe avian dynamics in terms of habitat state changes as well as climatic change.

**Statement of Problem.** Change in land use patterns is a determinant factor influencing avian species status and trends in North America, and thus, central to discussions about sustainable landscapes and strategic habitat conservation. These considerations have been extended to include the potential effects of global climate. Changes in avian species distribution and abundance are expected to be pervasive as they may affect both landcover and land use practices. In this work, we propose to use Breeding Bird Survey data and the patch occupancy analytical framework to understand current and future avian distribution patterns and potential for sustaining populations based on patch occupancy dynamics. Specifically, the analytical framework allows us to estimate rates of local extinction and colonization given changes in landcover and landcover and use, and predict a range of dynamics in the future in response to global climate change. As such, this work will also generate expressions of population persistence as a function of land use. The foundation of this work will be an assessment of land use change over the past 27-36 years and expected changes based on global climate change models. The modeling framework and findings of this work will facilitate the creation of decision support tools for managers and better inform strategic habitat conservation planning and monitoring processes.

We also expect that the approach developed here for avifauna will serve as a framework for other species and taxonomic groups as the necessary data are collected and organized. In particular, we underscore the statistical methodology and software that will be developed in dealing with species range dynamics, as possibly influenced by climate change. We also emphasize that the broad scientific approach proposed in this work has the potential to provide the basis for a general theory of climate change effects that can be useful to other DOI scientists and managers. The

hypothetico-deductive approach of testing predictions of *a priori* hypotheses about species occurrence and occupancy dynamics for different portions of species ranges can provide a basis for a theory that permits at least predictions for species and locations other than those studied.

### **Objectives.**

1. Quantify processes underlying current avian distribution patterns, and predict potential for sustaining populations based on patch occupancy dynamics and projected land use changes,
2. Quantify responses of ecosystem components (N. American landbirds) to recent climate variation and change. Specifically, test hypotheses about recent changes in species ranges corresponding to climate change during the last 3 decades.
3. Develop models predicting future range dynamics in response to predicted climate change.

### **Relationships to other proposed research**

Climate change projections.— We will apply downscaled data obtained from project I (Developing Regionally Downscaled Probabilistic Climate Change Projections) to produce finer-scale temperature and precipitation scenarios for avian assessment at multiple spatial scales. Investigators will develop a synthesis of historical trends and future scenarios using expression of relevant climatic covariates to avian annual cycle such as drought frequency and intensity, days below freezing, growing season length, and frequency of hurricanes.

Historic and projected landscape conditions.— We will use data on historic landscape conditions and estimates of range of change in the Southeast since 1973 to estimate habitat-related changes in bird distribution and vital rates with emphasis on changes as a function of climate change (see below). Data will be derived from Project III (Climate Change in the Southeastern U.S. and its Impacts on Bird Habitats) conducted by the Alabama Cooperative Research Unit. Likewise, we will use data generated by Project IV (Designing Sustainable Landscapes: Climate and Land Use Change Projected Impacts on Priorities Species Habitats in the Southeastern U.S.) , which will produce region-wide projections of urban growth and habitat dynamics from 2001 to 2100, to predict potential impacts on avian distribution and vital rates.

Structured Decision Making/Adaptive Management Framework – The results of this project will be used by AL CFWRU under project VII (Optimal Conservation Strategies to Cope with Climate Change). The results are unique in that provide the opportunity to incorporate spatial and temporal variation in vital rates (see Conroy and Noon 1996) to determine the availability, quality, and distribution of resources (habitat), the effects of conservation actions, and the predicted effects of null, low, medium, and high degrees of climate change on populations of focal species. This effort will also incorporate structural and parametric uncertainty in the effects of climate change on habitats, the effectiveness of conservation actions, and the response of populations using Bayesian Belief Networks and simulation modeling (Marcot et al. 2006a,

2006b, Nyberg et al. 2006). Development and sensitivity analysis of the decision model will lead to the identification of critical information needs for conservation planning, research, and monitoring.

### **Methods:**

We will use occupancy models to discern processes behind occurrence patterns of avian species in response to observed changes in habitat at landscape levels in the southeastern U.S (MacKenzie et al. 2006). At the core of this effort will be Breeding Bird Survey data (1992 to 2001) and remotely-sensed data. For this particular set of analyses, BBS routes will be divided into 4 segments of 5.6 km, separated by 4.8 km, to minimize habitat heterogeneity. The 8 stops per segments are treated as geographic replicates permitting estimation and accommodation of species-specific detection probabilities. Failure to deal adequately with detection probabilities is an important shortcoming of the vast majority of macroecological research. Landcover data are available for 1992 and 2001 (NLCD), which will be used to assess habitat change between landcover sets and species-habitat associations. Candidate set models (*a priori* hypotheses) will be formulated on the basis of the species' life history and habitat requirements, an effort aimed at capturing the species' ecological (landscape) basis for sensitivity. Processes (patch dynamics) and inferences about "sustainability" will be derived from relationships between habitat states (and suitability) and expressions of rates of patch extinction and colonization. We will use single-season, and a combination of multi-season and integrated habitat-occupancy models to conduct analyses. The latter two modeling frameworks will allow estimating colonization and extinction rates, incorporating habitat change and climate as covariates, or joint consideration of habitat transition probabilities as well as processes of interest (colonization/extinction) to gain additional insights on the interplay among habitat, climate and vital rates of interest.

BBS data will also be used to assess range dynamics of selected species. Species selection will be based on BBS data since 1973, provided they are reasonably well-sampled and we can develop general range maps. We will define near-boundary locations as those falling within some specified distance of the boundary (likely some multiple of BBS route length; e.g., either 40 or 80 km). For each selected species, we will use multi-season occupancy modeling (e.g., MacKenzie et al. 2003, 2006), in conjunction with the BBS data, consisting of counts on each of 50 stops on each route. The parameters of biological interest, local probabilities of extinction, colonization and occupancy, will be modeled as functions of route location within the species range, with competing hypotheses represented by different constraints on location-specific parameters. We plan to use an autologistic function in which patch dynamic-parameters (local extinction, colonization, occupancy) are modeled as possible functions of occupancy of neighboring locations. This modeling is made difficult by the fact that occupancy of neighboring locations is not known, either because locations are not sampled (no BBS route) or because sampling yields no detections (BBS route is present but the species is not detected there). Because of imperfect detection, nondetection is an ambiguous event that can result from either true absence of the species or presence but nondetection. The inference approach that we will likely use (see below) permits prediction of occupancy status of neighboring locations, thus providing a basis for inference about neighborhood effects. Model selection approaches will be used to decide on the most useful models, and the estimated signs, magnitudes and variances of model coefficients will

be used to judge degree of correspondence of estimates with hypothesis-based predictions. The second set of hypotheses about decadal changes will use similar modeling as above with the addition of parameters describing the rates of change in probabilities of local extinction and colonization at different locations. We can use either likelihood-based approaches or Markov Chain Monte Carlo Bayesian approaches to model fitting and estimation, and will likely opt for the latter approach. In addition to providing a good approach for dealing with the autologistic modeling (which would be more difficult to implement with a frequentist approach), the Bayesian approach provides a natural framework for mapping based on current and projected (using decadal models) range dynamics (e.g., see Kery et al. 2005, Royle et al. 2005).

Project Status: Focal species (12) have been selected for preliminary analyses within the South Atlantic Coastal Plain (SAMBI region) based on BBS data collected from 1992 to 2001. These same data will be used to select and apply climate covariates to occupancy models to assess, after controlling (blocking) for habitat, the influence of climate on avian vital rates (i.e., extinction and colonization rates). The work in the South Atlantic region serves as a benchmark, which along with a substantially refined modeling framework and historical landscape and climate data (see methods), will be applied to Southeastern United States to model range dynamics and responses to predicted habitat and climate changes.

#### Year 1

- Complete patch dynamic models for the South Atlantic Region (SAMBI)
- Recruit Post-Doctoral Research Associate
- Select species and assign each BBS route to the appropriate range location category.
- Build joint database incorporating habitat and climate models output.

#### Year 2

- Develop software and implement analyses for selected focal species (2-4 species).
- Complete analyses for remaining species.

### **Budget Request**

FY09: \$80,000 – Support for Post-Doctoral Research Associate

FY10: \$80,000 – Support for Post-Doctoral Research Associate

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## TECHNICAL PROPOSAL VI

### **Title: Multi-resolution Assessment of Potential Climate Change Effects on Biological Resources: Aquatic and Hydrologic Dynamics**

*Principal Investigators: J. Peterson, L. Hay, K. Odom, W. Hughes, R. Jacobson, J. Jones, M. Freeman, UGA/USGS. Funding Request FY2009 - \$60,000, FY 2010 \$365,000; FY 2011 \$385,000; FY 2012 \$200,000; FY 2013 \$200,000; FY2014 \$200,000*

### **Introduction**

This component of the Southeastern Integrated Assessment will develop information and modeling approaches to help resource managers assess potential effects of climate change on biological resources. The specific focus of this research is on aquatic biota, especially freshwater fishes and mussels, and on improving our ability to answer questions concerning how species are likely to respond to climate-induced hydrologic change.

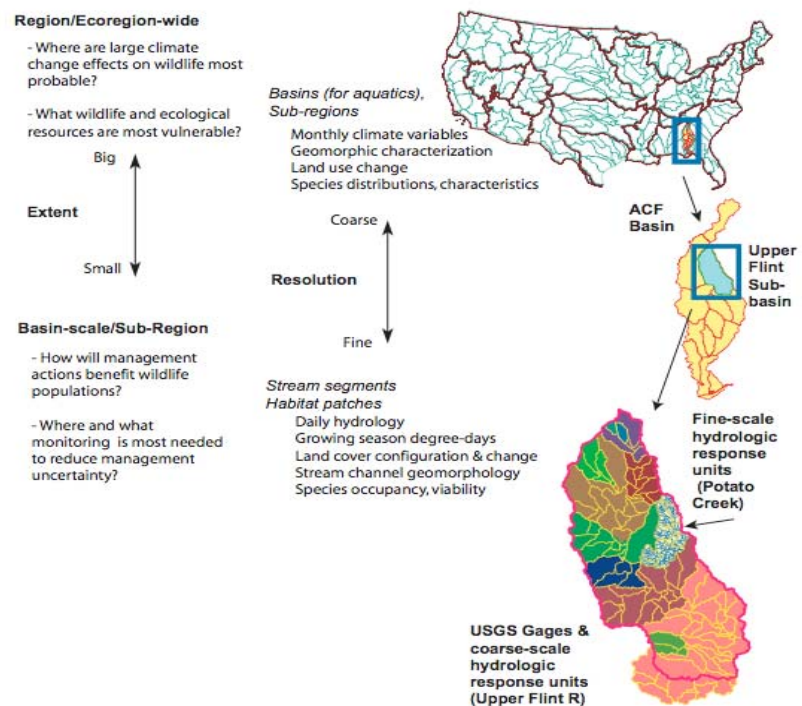
This research has two, interrelated objectives. One is to develop tools that wildlife resource managers can use to predict climate-change effects across large regions and at local landscape-scales. The appropriate resolution for analyzing the effects of climate change will differ depending on the scope of the resource question and the limits of potential management actions (e.g., from regions or ecoregions, to local landscapes that support particular species of concern). Thus, a multi-resolution approach to understanding and predicting climate-change effects on wildlife and other ecological resources will be essential for developing effective and cost-efficient conservation strategies. Our first objective is to develop modeling approaches to assess climate-change effects on aquatic biota at two spatial extents and two levels of resolution, each with specific management questions, response units, data requirements, and associated costs (Figure 1). For each level of resolution, we will work with resource managers to identify key management questions and objectives and to conceptualize links between climate change, wildlife resources, and management actions.

Our second objective is to evaluate how the choice of model resolution affects assessment of ecological sensitivity to changes in climate, hydrology, land cover dynamics, surface water dynamics and land use. Assessments are often made at relatively coarse scales of resolution; for example, as in initial evaluations of potential effects of land use or climate trends on wildlife over large geographic areas. However, the processes that link climate, land cover and management to wildlife resources frequently occur at finer spatial scales than may be captured by coarse-grain assessments (e.g., hydrologic alteration in specific river reaches that support imperiled species; strategic conservation of population source habitats). Conversely, conditions characterized at larger spatial scales frequently set boundary conditions for local landscapes; for example, isolation of headwater rivers by downstream dams. It is thus particularly important for designing future assessment methods, that researchers and managers understand changes in the information content of differing measures of ecological, hydrologic, terrain and geomorphic characteristics in relation to changes in measurement scale.

Phase I of the project will develop and demonstrate a multi-resolution approach to assessment in the context of the Apalachicola-Chattahoochee-Flint (ACF) river basin, chosen because the basin supports multiple fish and wildlife species of conservation concern to Federal and State managers, is regionally important for water supply, and has been a recent focus of complementary research, providing an empirical basis for tool development. Using probabilistic projections of climate change developed for this integrated assessment, we will model effects on aquatic biota at coarse (i.e., the entire ACF basin) to fine (i.e., stream networks within the ACF) resolutions, providing estimates of biological responses for alternative climate scenarios and, at finer resolutions, potential management actions. In Phase II, researchers will confer with resource managers to examine usefulness of coarse- and fine-resolution models for supporting biological planning and conservation design, as defined under Strategic Habitat Conservation, and to explore how appropriate model-resolution may depend on characteristics of species, landscapes and limiting factors. Understanding and models developed in Phase I will then be used to identify species and ecoregional areas that are especially vulnerable to projected climate-change effects, to develop models at appropriate resolutions for those species (terrestrial and aquatic), and to design data collection strategies that will address the largest sources of uncertainty identified in Phase I.

## Methods

Our approach is based on the understanding that water availability and aquatic species dynamics are largely influenced by precipitation and temperature modified by the landscape and geomorphic factors that influence runoff, sediment delivery, and stream morphology. Thus, understanding and predicting potential climate change effects on the distribution and dynamics of aquatic species, and on water availability for human needs, will require integrating hydrology and



**Figure 1.** A graphical representation of the proposed multi-resolution approach for assessing climate-change effects on ecological resources.

land cover dynamics across the geomorphic template that forms aquatic habitat, and then interpreting projected changes in terms of species responses to alternative management actions.

Project scientists will develop models for linking hydrology and land cover to aquatic species at basin to stream-segment levels of resolution, to support decision-needs at regional to local levels (see Figure 1). These models will be loosely coupled through use of the web-based data service being developed by the USGS North Carolina Cooperative Fish and Wildlife Research Unit. In addition to the dissemination of nationally downscaled climate change data sets, this webservice will be used to facilitate dissemination of our model inputs and outputs. Component models and approaches are described below, followed by procedures for predicting species responses at coarse and fine resolution.

### ***Component models***

*Hydrologic modeling structure* - Hydrologic models will be developed using the Precipitation Runoff Modeling System (PRMS; Leavesley et al. 1983, Hay and Umemoto 2006). PRMS (1) simulates land surface hydrologic processes including evapotranspiration, runoff, infiltration, and interflow estimated by balancing energy and mass budgets of the plant canopy, snowpack, and soil zone on the basis of distributed climate information (temperature, precipitation, and solar radiation); (2) simulates hydrologic water budgets at the watershed scale with temporal scale ranging from days to centuries; and (3) integrates with models used for natural resource management or other scientific disciplines. For the ACF application, PRMS will require research and development of new multi-resolution capabilities. This new development in PRMS will provide methods for addressing multiple spatial extents and resolutions within a single model structure, and will support a variety of temporal simulation contexts (historic, current, and future).

Daily time-step PRMS models will be developed at spatial scales corresponding to (1) major “sub-basins” (approximately 8-digit HUICS) within the ACF, (2) stream gage locations (nested within sub-basins), (3) coarse-scale response units (nested within watersheds defined by stream gage locations), and (4) fine-scale response units corresponding to stream segments (Figure 1). Models for sub-basins will be used in coarse-resolution assessments; the smallest two levels of resolution (coarse-scale and fine-scale response units) will be appropriate for modeling species occupancy dynamics, explained below. For the fine-scale response units, pilot models of stream temperature (using, e.g., Stream Network Temperature model, SNTMP) will be developed to allow investigation of the potential magnitude of change in seasonal stream temperature patterns under climate-change scenarios.

PRMS simulations for future conditions at each resolution will be facilitated through use of the web-based data service being developed by the USGS North Carolina Cooperative Fish and Wildlife Research Unit. This will contain the downscaled GCM information needed to run PRMS. Urbanization and land cover projections developed by the other research teams and incorporated into the web-based data service will be used in conjunction with the downscaled GCM output to produce the future PRMS projections.

*Geomorphic characterization and stream channel classification* - Geomorphic models will be developed for coarse- and fine- resolutions to characterize variation in (1) basin topography, using conventional DEM data and, for a sub-basin within the ACF, high-resolution LIDAR, and field

data; and (2) channel network structure and controls on the spatial distribution of persistent habitat features (deep pools, bedrock riffles, bedrock-constricted reaches) that influence colonization by fishes and other aquatic biota. At the stream network scale, models will be developed for predicting ecologically relevant channel-morphology classes, for use in species occupancy models. We hypothesize that channel form and bed sediment composition can be used to describe ecologically distinct stream classes that differ in how flow variation affects habitat and population processes. We will thus develop and test models for classifying stream segments according to form (e.g., relative width and depth dimensions) and sediment (e.g., accumulation of fine alluvium) from remotely-sensed topographic data. Regional classifications developed from coarse-scale data will be compared with basin-scale classifications developed from fine-scale data, and with field-based measurements, to assess information content/cost ratios over multiple scales and resolutions.

*Terrain characterization, and land cover and surface water dynamics* - Multi-resolution landscape dynamics databases including latent heat, biomass indices and multiple indices of land cover “disturbances”, and surface water body size and distribution will be developed using TM/ETM+ scenes spanning 1983-2008, a revised AVHRR vegetation index database for 1989-2006, and atmospherically-calibrated Landsat scenes. Deriving and analyzing pertinent landscape variables from remote sensing data allows the use of vegetation and surface water dynamics to improve hydrologic models (Viger et al., in preparation). These data also support direct measures of rates of change in land cover and extent of surface water (e.g., wetlands and constructed storage), used in turn to relate effects of climate, land use and hydrologic dynamics on riparian communities. Derived variables will include sub-watershed flow retention (through reservoir and storm pond survey), land change frequency analysis, spatially distributed evapotranspiration modeling, and floodplain vegetation dynamics. As above, landscape and surface water dynamics estimated for larger scales from fine-resolution assessments will be compared to equivalent estimates based on coarse-resolution data, to investigate influence of resolution on information content.

*Species response models* – To support large-extent, coarse-resolution assessment we will develop models that use species characteristics (e.g., reproductive traits, dispersal abilities, habitat affinities) to predict species vulnerability to changes in differing climate variables provided by the probabilistic projections of climate change. Species-specific distributions for freshwater fishes and mussels within the ACF will be mapped at coarse resolutions from available databases (e.g., Brim Box and Williams 2000; Georgia Museum of Natural History). Species traits will be assigned from published and unpublished data sets. Coarse-scale assessments will target fish and mussel species that are identified as ‘priority targets’ by regional USFWS and state resource managers.

For fine-resolution assessment, we will develop multi-state, multi-season occupancy models to project species occurrences at a stream segment scale for two sub-basins within the ACF, the Piedmont and Coastal Plain portions of the Flint River basin. These two sub-basins are of interest because they support federally-listed species of unionid mussels as well as species-rich fish assemblages within stream networks that are minimally influenced by large reservoirs. Thus, each of these sub-basins is considered important to long-term conservation of native biological diversity. Models will permit comparisons of simulated responses by fishes and mussels to

projected climate changes between Piedmont and Coastal Plain settings.

### ***Assessing Climate-Change Effects on Biota***

*Coarse-resolution approaches* - We will develop two modeling approaches, expert judgment and empirical simulation, for assessing the response of aquatic biota to climate change at the coarse-level. One objective will be to identify distinct costs and benefits for each approach, to help inform choices of how to conduct coarse-level assessments across the region. We will initiate the process by conferring with regional USFWS and state resource managers in a facilitated workshop to identify priority species targets, management objectives and decision alternatives appropriate to differing levels of resolution.

The expert judgment approach will be similar to that used by the USDA Forest Service to evaluate the response of stream habitats and salmonids to alternative land management strategies in the Pacific Northwest (Reiman et al. 1999). We will assemble an expert team of aquatic ecologists, physical scientists and resource managers familiar with the ACF system that will develop a conceptual model of the expected response of the priority species targets to changes in climate, accounting for geomorphic characteristics, landscape dynamics, system fragmentation, and other relevant features identified by the expert team. To allow the models to be applied to coarse-resolution landscape units with different species pools, the model will focus on predicting the response of species based on life history characteristics (e.g., reproductive strategies, dispersal abilities). The conceptual models will be parameterized using information from published studies, existing (unpublished) data, and expert judgment. Climate-change effects on priority species targets throughout the ACF basin will then be assessed using outputs from hydrologic, terrain and stream geomorphic models. For example, coarse-level projections of monthly discharge and other flow variables identified by the expert team as likely drivers of species persistence will be extracted for ACF sub-basins from PRMS models, under differing probabilistic climate-change projections. Similarly, geomorphic (e.g., mean channel slope; occurrence of bedrock shoals; system fragmentation) and land use/land cover characteristics will be summarized for sub-basins, for those variables identified as drivers in the coarse-resolution models.

We anticipate that the expert judgment approach will be the most feasible coarse-level approach to apply across a large and diverse region, such as the Southeast. However, the model will not be directly linked with fine-resolution models, which could complicate stepping-down assessment results to support decision-making at resolutions relevant to local populations. To directly link the fine-resolution (described below) and coarse-resolution approaches, we will develop models for estimating changes in aquatic species distribution and persistence at the sub-basin scale, using the inputs and predictions from the fine-scale simulation modeling. Summary indices of projected changes to the climate and landscapes at the sub-basin scale will be calculated from the corresponding fine-scale estimates. For example, changes in the timing or frequency of high flows will be calculated from annual summaries of seasonal high-flow estimates from fine-resolution hydrologic models (an input to the fine-scale ecological response models). Similarly, outputs from the fine-scale ecological response models (e.g., stream segment occupancy rates) will be summarized at coarser scales. We will then relate the simulated coarse-level changes in the biota to the predicted coarse-level changes in inputs to the fine scale model (e.g., discharge, temperature, land change) using hierarchical models (Bryk and Raudenbush 2002). Similar to the

expert judgment modeling approach, we will use life history characteristics of the species to inform the species response models.

*Fine-resolution approach.* - Our fine-resolution models are based on the assumption that at relatively large spatial extents and long time-frames, the dynamics of stream-dwelling populations primarily consists of the extirpation (or persistence), colonization, and reproduction of local populations. Thus, our fine-resolution approach will model response of fish and mussel populations to discharge, temperature, landscape dynamics, and stream geomorphic characteristics using stochastic, multi-state stream segment occupancy models. The models will simulate the colonization, reproduction, and persistence dynamics of individual species in stream segments. The occupancy models will operate on an annual time step with initial species presence randomly assigned to each segment using existing species-presence models (Ruiz and Peterson 2007). During each time step, species-specific colonization, reproduction, and extinction probabilities will be estimated as functions of discharge, temperature, geomorphic stream segment characteristics, and land use using existing empirical models (Peterson and Shea *in prep*). These transition probabilities will then be used to simulate the occupancy of individual segments. Similar to the coarse-resolution approach, we will examine the influence of species traits on the sensitivity of aquatic biota to changes in climate and landscapes. Discharge, temperature, geomorphic stream segment characteristics, and land use dynamics will each be modeled at fine-resolution as described above for each model component.

For all modeling approaches, we will incorporate parametric (statistical) uncertainty by assigning probability distributions to model parameters. Structural uncertainty will be explicitly considered by postulating feasible alternative models, with each model representing a hypothesized relationship among inputs, system dynamics, and objectives (Williams et al. 2002). The final structure of the coarse-resolution models will be in a user-friendly format, such as a Bayes network (Peterson and Evans 2003), to allow biologists to evaluate the relative value of alternative decisions. The fine resolution models also will be placed in a user-friendly format that will allow biologists to run simulation scenarios based on potential management actions. Sensitivity analysis will then be performed on all models and model inputs to identify and prioritize the key uncertainties.

## **Phase II**

Phase I will provide comparative models of climate-change effects on fishes and mussels, as estimated using probabilistic projections of climate change in (1) coarse-resolution measures of hydrology, landscape and geomorphic features to predict relative effects on species in differing portions of the ACF basin; (2) fine-resolution models of species occupancy dynamics within sub-basins of the ACF, as driven by hydrology, temperature, landscape and geomorphic features measured at finer-scales; and (3) coarse-resolution models derived by aggregating results from fine-resolution models. Sensitivity analysis will identify what types of additional data would have the greatest effect in reducing uncertainty in model predictions. Simultaneously, partner research teams will have been developing coarse- and fine-scale models for bird species in the Southeast region.

Building on these Phase I models, researchers will confer with resource managers to examine the usefulness of coarse- and fine-resolution models for understanding potential climate-change effects with respect to specific conservation goals. In particular, it will be of interest to explore how the appropriate model-resolution may depend on characteristics of species and landscapes, and on the factors that most limit priority species. This will provide a basis for developing models that integrate conservation objectives for terrestrial and aquatic priority species. Phase I results will also be used to explore methods for modeling linkages across resolutions so that effects of conservation actions can be analyzed in terms of predicted effects at multiple levels.

We will work with regional fish and wildlife managers to identify priority species and ecoregional areas that appear especially vulnerable to projected climate-change effects, and where multi-resolution model development could help guide conservation strategies. Understanding and models developed in Phase I will then be used to develop models at appropriate resolutions for those species (terrestrial and aquatic), and to design data collection strategies that will address the largest sources of uncertainty identified in Phase I. Model components would include probabilistic projections of climate change, spatially-explicit hydrology, land use and land cover dynamics, and the geomorphic/landform template that constrains and defines habitat characteristics, in a context to predict distributions of species and assemblages under climate and management scenarios.

#### Timeline

##### Year 1

- Conduct workshops with management agencies; convene expert panels and develop conceptual models for coarse-resolution assessments
- Develop PRMS modeling structure for ACF
- Develop datasets for land cover dynamics, surface water dynamics, geomorphic characterization
- Assess accuracy of stream-channel classifications based on geomorphic characteristics modeled from coarse- and fine- resolution data
- Develop databases for testing alternative hypotheses for mechanisms structuring aquatic biota assemblages in relation to landscape and climate changes

##### Year 2

- Complete coarse- and fine-resolution assessments for priority ACF species targets under climate-change scenarios
- Assess model sensitivity to differing sources of uncertainty
- Prepare findings for publication

##### Year 3 - Phase II

- Confer with regional fish and wildlife managers to (1) compare and explore coarse- and fine-resolution modeling results; and (2) identify priority species and geographic areas for expanding modeling efforts
- Design data collection strategies that would address large, tractable uncertainties in modeling fish and wildlife responses to climate change
- Initiate construction of hydrologic models, species and landscape data sets for expanded model efforts

- Develop modeling strategies for linking terrestrial and aquatic species in model-based, spatially-explicit conservation strategies

#### Years 4-5

- Construct models for identified priority species
- Incorporate probabilistic climate change projections as these are updated by climate-modeling team
- Evaluate model sensitivity
- Confer with resource managers in an adaptive loop to ensure models target conservation issues

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## TECHNICAL PROPOSAL VII

### **Title: Optimal Conservation Strategies to Cope with Climate Change**

**Principal Investigator:** Dr. James (Barry) Grand, Leader, USGS, Alabama Cooperative Fisheries and Wildlife Research Unit, Auburn University, AL

We propose to develop a framework for using Adaptive Management (AM) and the principles of Strategic Habitat Conservation (SHC) to address the potential impacts of climate change on terrestrial and aquatic species in the southeastern United States. AM provides an ideal framework for the establishment and attainment of conservation objectives in the face of tremendous uncertainty, while SHC is specifically designed to address issues associated with establishing and maintaining target populations. Although it can be argued that SHC is only applicable at landscape scales, the iterative nature of both processes is essentially parallel.

AM as defined in the Department of Interior Technical Guide (Williams et al. 2007) involves Assessment, Design, Implementation, Monitoring, Evaluation, and Adjustment phases, while SHC requires Biological Planning, Conservation Design, Implementation, Monitoring, and Applied Research. The Assessment and Design phases of AM corresponds closely with requirements associated with Biological Planning and Conservation Design—identification of focal species and their population status, development of population objectives, determination of habitat requirements, inventory of the available resources (habitat), determining habitat objectives, and the desired landscape configuration. Additionally, AM provides explicitly for the accommodation of stakeholder input in the establishment of these elements. These steps logically lead to the development of models that predict the results of conservation actions (i.e. management or policy) referred to in SHC as decision support tools. An emergent property of using either process in a structured decision making context is the identification of fundamental objectives that describe the important outcomes of conservation actions, as well as means objectives that describe the actions themselves. This logically leads to the correct identification of the information necessary to understand the state of the system and the models necessary to predict the outcome of system dynamics resulting from changing environments or conservation action.

The development of decision support tools or predictive models in the case of climate change is complicated by structural as well as parametric uncertainty. With adequate forethought AM can be used to address decisions that are plagued by both sources of uncertainty. By structural uncertainty, we refer to a lack of complete knowledge of the system (i.e., the environmental model). Thus, AM may be particularly well-suited to decisions related to climate change, since there is great debate regarding nature and magnitude of change. Fish and wildlife agencies are typically faced making decisions in stochastic, but relatively constant environments. Thus, competing environmental models may be used to predict future systems states as well as the nature of species' response. Parametric uncertainty refers to the degree of response elicited by conservation actions. Addressing both sources of uncertainty will require the ability to make relatively precise predictions regarding the environment, the ensuing changes to the resources required by terrestrial and aquatic, and the effects and responses to conservation actions. Thus, data and models that operate at increasingly finer scales, such as those proposed in the projects

outlined here will be required to learn how the system is evolving over time and whether conservation actions are leading to progress towards the stated objectives.

Finally, AM and SHC require the establishment of implementation plans and monitoring programs that are used to track progress towards objectives. Over time, both types of uncertainty can be reduced through monitoring programs that address the key components and relationships that define the system state. The identification of these key components is an emergent property of the process of correctly describing system structure.

## **Objectives**

The primary objective of this project is to develop a framework to implement SHC using AM to determine optimal conservation strategies that incorporate the potential effects of climate change on fish and wildlife populations at an ecoregional scale.

Based on input from stakeholder in the fish and wildlife conservation community:

1. Identify focal species for planning conservation actions within each ecoregion. Focal species should represent the species most sensitive to resource and process limitations in the southeastern region (Lambeck 1999) and should represent a broad array of taxa.
2. Assess the state of populations of focal species based on the best available information. This may include survey data (e.g. Breeding Bird Surveys, mid-winter waterfowl surveys, North American Amphibian Monitoring Program) or expert opinion.
3. Determine population objectives and habitat objectives for focal species that will ensure their persistence.
4. Identify and quantify the effects of management and policy alternatives for the conservation of focal species.

Based on the best available and related projects in this assessment:

5. Develop habitat relationship models for focal species that will be suitable for predicting population responses to climate change and conservation actions.
6. Determine optimal conservation strategies based on the identified management and policy alternatives that are most likely to sustain populations of focal species.
7. Identify key elements for monitoring that will reduce uncertainty regarding the effect of climate change on terrestrial and aquatic populations and their habitats and measure progress towards population and habitat objectives.

## **Approach**

### Workshops

The first four objectives will be addressed through a series of facilitated workshops for a select group of decision makers and technical experts (stakeholders) from the fish and wildlife conservation community in each Bird Conservation Region of the southeast region. Workshop participants should represent a cross-section of state, federal, and non-governmental agencies committed to long-term conservation and participation in the AM process. During the workshops, we will re-evaluate species identified as potentially vulnerable to climate change using a process adapted from Lambeck (1999) to identify species and habitats that are most sensitive to resource (patch size, habitat composition, and connectivity) and process (e.g., alter hydrology, altered fire regimes, invasive species, non-native predators) limitations. The species most sensitive to these environmental stressors, especially those expected to be most affected by climate change will be used as focal species for SHC and AM processes. Similar to the suggestions of Lambeck (1999) we will consider species whose regional populations are of conservation concern and those considered especially vulnerable to the effects of climate change.

The current state of each focal species will be determined through the use of existing data (e.g., Breeding Bird Survey) or expert opinion solicited during technical meetings following the workshops. We will establish population objectives for focal species beginning with existing conservation plans (e.g., North American Waterfowl Management Plan, Shorebird Conservation Plan, Northern Bobwhite Conservation Initiative) and where necessary adjusting them to meet long-term objectives for sustainability and utility. Where sufficient data exists and published studies are not available we will use population viability analyses to establish population objectives related to persistence times.

Workshop participants will be asked to identify ecoregional scale management and policy alternatives that may affect populations of focal species. Alternatives should include planned actions such as Farm Bill programs, carbon sequestration, conservation land acquisition, and wetlands protection. We will use input from workshop participants and existing documentation to determine the proposed scope, magnitude, and likelihood for success of the effect of each action with regard to land use and land cover each ecoregion.

When they are available, we will use habitat relationship models developed by researchers at the NC CFWRU that incorporate spatial and temporal variation in vital rates (see Conroy and Noon 1996) to determine the availability, quality, and distribution of resources (habitat), the effects of conservation actions, and the predicted effects of null, low, medium, and high degrees of climate change on populations of focal species. We will incorporate structural and parametric uncertainty in the effects of climate change on habitats, the effectiveness of conservation actions, and the response of populations using Bayesian Belief Networks and simulation modeling (Marcot et al. 2006a, 2006b, Nyberg et al. 2006). Development and sensitivity analysis of the decision model will lead to the identification of critical information needs for conservation planning, research, and monitoring.

### **Timeline**

#### Year1 (Phase 1)

- Conduct initial stakeholder workshops in each ecoregion.
- Identify focal species for planning conservation actions within each ecoregion.
- Assess the state of populations of focal species based on the best available information.
- Determine ecoregional population objectives for focal species
- Identify management and policy alternatives.
- Develop structure of the decision model(s)

#### Year 2 (Begins Phase II)

- Conduct additional stakeholder workshops to review and refine focal species selection, population objectives, and decision alternatives
- Develop quantitative models for the effects management and policy alternatives on habitats
- Review and refine habitat models for focal species response
- Refine structure of the decision model(s)

#### Year 3

- Sensitivity analyses
- Identification of key monitoring components and applied research needs

#### Year 4

- Preparation of final reports, products, and publications
- Outreach workshops at SEAFWA meeting and 2 other locations in SEAFWA region

#### **Literature Cited**

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**Budget**

<b>Item</b>	<b>Year 1</b>	<b>Year 2</b>	<b>Year 3</b>	<b>Year 4</b>	<b>Total</b>
<b>Salaries</b>					
Research fellow II (postdoc)	\$ 51,400	\$ 53,456	\$ 55,594	\$ 57,818	\$ 218,268
Graduate Research Assistant (Ph.D. - 2)	\$ 36,200	\$ 36,200	\$ 36,200	\$ 36,200	\$ 144,800
Research Assistant I (0.75 FTE)	\$ 23,250	\$ 24,180	\$ 25,147	\$ 26,153	\$ 98,730
Benefits for full-time staff (28.5%)	\$ 21,275	\$ 22,126	\$ 23,011	\$ 23,932	\$ 90,345
<b>Total Salaries &amp; Benefits</b>	<b>\$ 132,125</b>	<b>\$ 135,962</b>	<b>\$ 139,953</b>	<b>\$ 144,103</b>	<b>\$ 552,143</b>
<b>Travel</b>					
<b>Workshop &amp; coordination travel</b>					
Airfares (\$200 ea.)	\$ 3,600	\$ 3,600	\$ 3,600	\$ -	\$ 10,800
M&IE (\$150/day)	\$ 10,800	\$ 10,800	\$ 10,800	\$ -	\$ 32,400
<b>Outreach (3 workshops at various locations)</b>					
Airfares (\$200 ea.)	\$ -	\$ -	\$ -	\$ 2,400	\$ 2,400
M&IE (\$150/day 3 workshops)	\$ -	\$ -	\$ -	\$ 1,800	\$ 1,800
<b>Total Travel</b>	<b>\$ 14,400</b>	<b>\$ 14,400</b>	<b>\$ 14,400</b>	<b>\$ 4,200</b>	<b>\$ 47,400</b>
<b>Supplies</b>					
Software licenses	\$ 3,000	\$ 3,000	\$ 3,000	\$ 3,000	\$ 12,000
Computers dedicated to modeling effort (3)	\$ 5,500	\$ -	\$ -	\$ -	\$ 5,500
<b>Total Supplies</b>	<b>\$ 8,500</b>	<b>\$ 3,000</b>	<b>\$ 3,000</b>	<b>\$ 3,000</b>	<b>\$ 17,500</b>
<b>Total for Indirects</b>	<b>\$ 155,025</b>	<b>\$ 153,362</b>	<b>\$ 157,353</b>	<b>\$ 151,303</b>	<b>\$ 617,043</b>
<b>AU Overhead (12%)</b>	<b>\$ 18,603</b>	<b>\$ 18,403</b>	<b>\$ 18,882</b>	<b>\$ 18,156</b>	<b>\$ 74,045</b>
<b>Total to AU</b>	<b>\$ 173,628</b>	<b>\$ 171,766</b>	<b>\$ 176,235</b>	<b>\$ 169,459</b>	<b>\$ 691,088</b>
<b>USGS Overhead (6%)</b>	<b>\$ 10,418</b>	<b>\$ 10,306</b>	<b>\$ 10,574</b>	<b>\$ 10,168</b>	<b>\$ 41,465</b>
<b>Total funding required</b>	<b>\$ 184,046</b>	<b>\$ 182,072</b>	<b>\$ 186,809</b>	<b>\$ 179,627</b>	<b>\$ 732,554</b>